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# Investigating the effect of air permeability and moisture on 2.5GHz textile microstrip patch antenna performance

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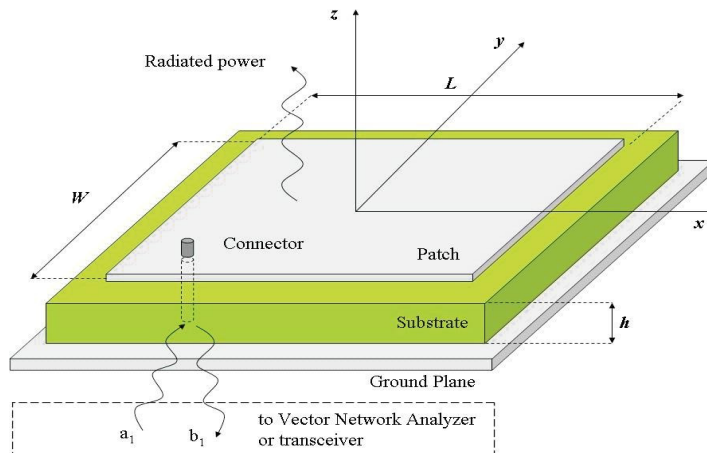
**Abstract.** When discussing textile antenna and its comfortable use, the effect of air permeability and atmospheric moisture are eminent factors which have direct influence on textile antenna transmission characteristics and comfort of the wearer when used practically. The rate of airflow under certain air pressure passing through any surface is termed as air permeability of that surface and amount of moisture regained by a material when exposed to varying environmental humidity ranges compared to dry weight of that material is its moisture regain. Fleece and spacer fabrics were selected each having different air permeability and moisture regain values but both fabrics constitute polyethylene terephthalate - PET. Microstrip patch antennas that resonate at 2.45GHz were constructed utilizing both textile fabrics. Spacer fabric has high air permeability and low moisture regain compared to fleece fabric. Spacer fabric is a knitted 3-dimensional structured fabric whereas fleece is nonwoven in structure. FlecTron® is utilized as the conductive part of the microstrip patch antenna. Antenna made off spacer fabric showed better transmission characteristics and are least altered due to change in humidity compared to antenna made off fleece fabric. In this research, we conclude that the selected textile spacer fabric, with its high air permeability and low moisture regain, is the most favourable textile material in the construction of textile antennas.

## 1. Introduction

Wearable textile systems create an improved quality of life by enhancing functionality of clothing. This new generation of garments has the ability to monitor bio-signals from the wearer and from the environment around the wearer of these garments. By wireless means, information is transferred to a base station through wearable antennas integrated into the outer garment of the wearer [1]. Microstrip planar antennas are low profile, comfortable to wear, light in weight, simple in design and robust to harsh environmental conditions. These antennas utilize electro textiles as conductive and dielectric textile material as insulating part of the antenna [2] as illustrated in Figure 1.

Antenna performance is affected when exposed to high humid conditions especially by altering relative humidity. By selecting proper textile materials, this effect can be minimized. Textile materials with the lowest moisture regain and highest air permeability least alter, when employed to construct antennas, electromagnetic properties and hence better performance can be obtained from antennas constructed from those materials. Textile material contains air cavities and their relative permittivity is situated between 1 and 2, whereas water has a much higher relative permittivity of 78 at 2.45 GHz frequency and 25°C [3]. Textile material used for wearing purpose, having high air permeability is advantageous, therefore substrates like foam are not advantageous. Also, low moisture regain value and low relative permittivity can be effective in the antenna construction and for its performance.





**Figure 1.** Geometry of Microstrip patch Antenna.

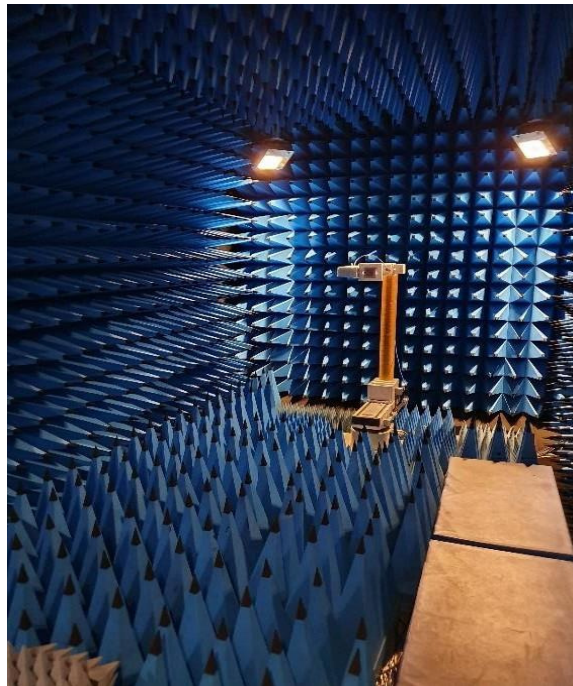
## 2. Materials and Method

In order to design an efficient microstrip patch antenna, selection of suitable textile materials was done. Textile materials having lowest possible permittivity, close to permittivity of air that is 1 together with high air permeability which allows any moisture if present in that material to evaporate more quickly and with low moisture regain are most suitable material properties to get high efficiency from antennas [4]. Spacer fabric which is a knitted 3-dimensional structure is chosen against fleece fabric which is nonwoven in structure as was used before in antenna construction [5]. Both are quite thick with sufficient difference in their air permeability values, their moisture regain values should be close to each other and they are suitable for the construction of microstrip patch antennas. Meanwhile, difference in air permeability allowed to check the effect on transmission characteristics for both antennas when relative humidity remains equal during transmission characteristics measurements.

FlecTron® is used as conductive electro textile to construct microstrip patch antennas. It is a copper plated nylon ripstop woven fabric with a surface resistivity of less than  $0.1 \Omega/\text{m}^2$  and air permeability of 97mm/sec. Both the knitted spacer fabric and fleece fabric constitute of the same PET material. The thickness of the textile materials was measured using *Digimatic Indicator* based on the ISO 5084 standard whereas the air permeability is measured under ISO standard 9237.

The extent to which a material is sensitive to moisture is defined as its moisture regain. Both textile fabrics were put in an oven for 5 hours under  $105^\circ\text{C}$  and weighed. Afterwards, both fabrics were put in conditioned room for 24 hours at  $20^\circ\text{C}$  and 65% relative humidity for conditioning, later these fabrics were weighed again. This procedure is followed under ISO standard 6471 (1-4). The moisture regain is then calculated by,

$$\text{Moisture Regain}\% = \frac{\text{Conditioned weight} - \text{Dry weight}}{\text{Dry weight}} \times 100 \quad (1)$$



**Figure 2.** Anechoic chamber room.

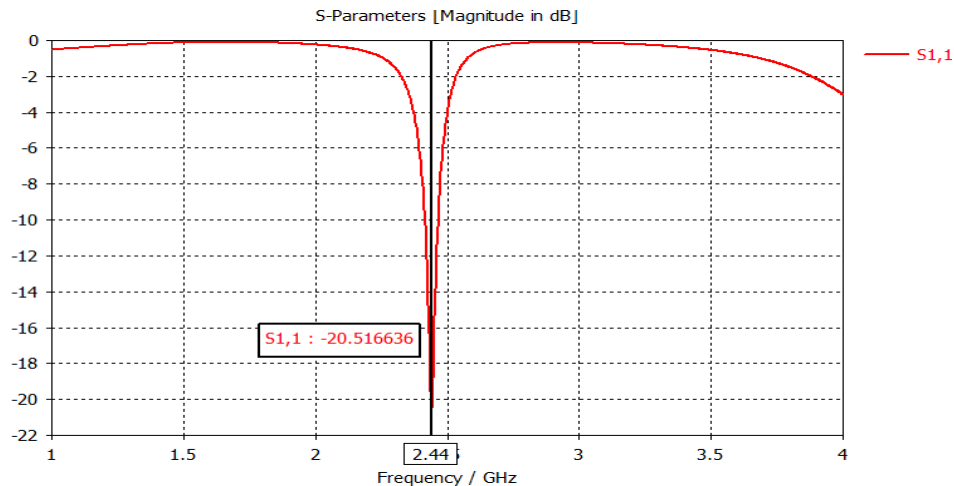
Two materials (fleece and spacer fabrics) chosen for microstrip patch antenna construction are moisture dependent, but one is less dependent than the other as moisture regain is different for both materials.

Reflection co-efficient ( $S_{11}$ ) is measured in an anechoic chamber shown in figure 2 by employing a *Vertical Network Analyzer* (VNA). Relative permittivity and loss-tangent of textile materials are determined by comparing simulated and measured resonance frequency of microstrip antennas. The constructed spacer fabric-based antenna is illustrated in figure 3. Antennas are simulated using *CST Studio Suite 2017* and constructed manually utilizing both fleece and spacer textile fabrics.



**Figure 3.** Spacer fabric-based microstrip patch antenna.

Both the antennas were put to conditioning again for 24 hours at 65% relative humidity and 25°C temperature and later measured their transmission characteristics.



**Figure 4.** Measured return loss for spacer fabric-based antenna.

### 3. Results and discussion

The dimensions of simulated spacer fabric-based antenna are given in table 1. The simulated dimensions for spacer fabric-based antenna proved accurate when antenna was constructed using spacer fabric as constructed antenna also resonates at 2.45GHz.

**Table 1.** Dimensions of simulated spacer fabric-based antenna.

Length of patch (mm)	Width of patch (mm)	Length of ground plane (mm)	Width of ground plane (mm)	Length of feed line (mm)	Width of feed line (mm)	Gap between feed line and patch (mm)
53	60	100	100	15	13.36	5

The transmission characteristics of spacer fabric-based antenna which is designed to resonate at 2.45GHz are illustrated in figure 4. SMA connector is employed to construct microstrip patch antennas. Antennas resonate at 2.45GHz when provided with 50Ω of impedance. The properties of FlecTron® conductive fabric, spacer fabric and fleece fabric are mentioned in table 2.

**Table 2.** Properties of fleece and spacer fabrics.

Materials	Permittivity ( $\epsilon_r$ )	Moisture regain (%)	Thickness (mm)
Fleece	1.25	0.65	2.56
Spacer	1.05	0.52	3

Air permeability was measured as an average or mean value of five different test results taken from five different positions of one fabric sample. Five different positions within the sample were chosen to see the difference in air permeability values within one sample. This procedure was followed for both fleece and spacer fabrics. An average or mean value with standard deviation for air permeability of the spacer and fleece fabrics are mentioned in table 3.

**Table 3.** Mean and standard deviation of air permeability test.

Material	Mean	Standard deviation
Spacer fabric air permeability (mm/sec)	2618.4	30.41
Fleece fabric air permeability (mm/sec)	610	14.61

Antennas constructed from both different textile materials resonate at 2.45 GHz ISM band. Main focus is kept on the sharp resonance peak rather than covering the entire communication frequency band because the peak position is related to the relative permittivity of textile material which changes when the relative humidity in the atmosphere changes. Influence of relative humidity at its particular value on antenna performance is examined by measuring return loss characteristics of both antennas.

It was observed that resonance peak for conditioned (65% relative humidity and 25°C) spacer fabric-based antenna is least altered when measuring its transmission characteristics compared to that of conditioned fleece fabric-based antenna at the same values of relative humidity and temperature. The results for the influence of increasing relative humidity ranging from 10% to 90% on transmission characteristics for both antennas are forthcoming. High air permeability of spacer fabric-based antenna helps to let the moisture in it evaporate more quickly, hence resonance peak is least altered at particular value of relative humidity and temperature. Whereas, due to the low air permeability of fleece fabric-based antenna, moisture remains for long in fleece fabric, due to this when transmission characteristics were measured, resonance peak is more altered.

#### 4. Conclusion

Because of the fact that high air permeability of spacer fabric-based antenna takes the least time to let the moisture from the antenna substrate evaporate more quickly, this will help achieve less shift of resonance frequency of that antenna. Whereas, fleece fabric-based antennas cannot allow moisture to dissipate in the atmosphere as quick as spacer fabric-based antenna does. Hence resulting in more shift of its resonance frequency. Another important factor is the relative permittivity of both antenna substrates. Spacer fabric has relatively lower permittivity than fleece fabric, almost as close to the permittivity of air. Water has relatively higher permittivity that is 78 at 2.45GHz and tangent loss is 0.15 at 25°C. So, the influence of humidity on transmission characteristics of antenna made from spacer fabric is less because spacer fabric has low moisture regain and high air permeability. Whereas, the influence of humidity on transmission characteristics of antenna made from fleece material is slightly more because of slight high moisture regain and low air permeability.

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